3.1: Two Types of Bonding

Concept Review Exercises

1. What is the octet rule?
2. How are ionic bonds formed?

Answers

1. The octet rule is the concept that atoms tend to have eight electrons in their valence electron shell.
2. Ionic bonds are formed by the attraction between oppositely charged ions.

Exercises

1. Why is an ionic compound unlikely to consist of two positively charged ions?
2. Why is an ionic compound unlikely to consist of two negatively charged ions?
3. A calcium atom has two valence electrons. Do you think it will lose two electrons or gain six electrons to obtain an octet in its outermost electron shell?
4. An aluminum atom has three valence electrons. Do you think it will lose three electrons or gain five electrons to obtain an octet in its outermost electron shell?
5. A selenium atom has six valence electrons. Do you think it will lose six electrons or gain two electrons to obtain an octet in its outermost electron shell?
6. An iodine atom has seven valence electrons. Do you think it will lose seven electrons or gain one electron to obtain an octet in its outermost electron shell?

Answers

1. Positive charges repel each other, so an ionic compound is not likely between two positively charged ions.
2. It is more likely to lose two electrons.
3.2: Ions

Concept Review Exercises

1. What are the two types of ions?

2. Use Lewis diagrams to illustrate the formation of an ionic compound from a potassium atom and an iodine atom.

3. When the following atoms become ions, what charges do they acquire?
   a. Li
   b. S
   c. Ca
   d. F

Answers

1. Cations have positive charges, and anions have negative charges.

2. 

3. 
   a. 1+
   b. 2−
   c. 2+
   d. 1−

Key Takeaways

- Ions can be positively charged or negatively charged.
- A Lewis diagram is used to show how electrons are transferred to make ions and ionic compounds.

Exercises

1. Identify each as a cation, an anion, or neither.
   a. H^+
   b. Cl^−
c. \( \text{O}_2 \)
d. \( \text{Ba}^{2+} \)
e. \( \text{CH}_4 \)
f. \( \text{CS}_2 \)

2. Identify each as a cation, an anion, or neither.
   a. \( \text{NH}_3 \)
   b. \( \text{Br}^- \)
   c. \( \text{H}^- \)
   d. \( \text{Hg}^{2+} \)
   e. \( \text{CCl}_4 \)
   f. \( \text{SO}_3 \)

3. Write the electron configuration for each ion.
   a. \( \text{Li}^+ \)
   b. \( \text{Mg}^{2+} \)
   c. \( \text{F}^- \)
   d. \( \text{S}^{2-} \)

4. Write the electron configuration for each ion.
   a. \( \text{Na}^+ \)
   b. \( \text{Be}^{2+} \)
   c. \( \text{Cl}^- \)
   d. \( \text{O}^{2-} \)

5. Draw Lewis diagrams for the ions listed in Exercise 3. Also include Lewis diagrams for the respective neutral atoms as a comparison.

6. Draw Lewis diagrams for the ions listed in Exercise 4. Also include Lewis diagrams for the respective neutral atoms as a comparison.

7. Using Lewis diagrams, show the electron transfer for the formation of \( \text{LiF} \).

8. Using Lewis diagrams, show the electron transfer for the formation of \( \text{MgO} \).

9. Using Lewis diagrams, show the electron transfer for the formation of \( \text{Li}_2\text{O} \).

10. Using Lewis diagrams, show the electron transfer for the formation of \( \text{CaF}_2 \).

11. What characteristic charge do atoms in the first column of the periodic table have when they become ions?
12. What characteristic charge do atoms in the second column of the periodic table have when they become ions?

13. What characteristic charge do atoms in the third-to-last column of the periodic table have when they become ions?

14. What characteristic charge do atoms in the next-to-last column of the periodic table have when they become ions?

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**Answers**

1. 
   a. cation
   b. anion
   c. neither
   d. cation
   e. neither
   f. neither

3. 
   a. $1s^2$
   b. $1s^22s^22p^6$
   c. $1s^22s^22p^6$
   d. $1s^22s^22p^63s^23p^6$

5. 
   a. $\text{Li}^+$, $\text{Li}^+$
   b. $\text{Mg}^+$, $\text{Mg}^{2+}$
   c. $\text{F}^-$, $\text{F}^-$
   d. $\text{S}^2-$, $\text{S}^{2-}$

7. $\text{Li}^+ + \text{F}^- \rightarrow \text{Li}^+ + \text{F}^- \rightarrow \text{LiF}$

9. $\text{Li}^+ + \text{O}^2- + \text{Li} \rightarrow 2\text{Li}^+ + \text{O}^2- \rightarrow \text{Li}_2\text{O}$

11. $1+$
3.3: Formulas for Ionic Compounds

Concept Review Exercises

1. What information is contained in the formula of an ionic compound?
2. Why do the chemical formulas for some ionic compounds contain subscripts, while others do not?
3. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. Mg$^{2+}$ and I$^{-}$
   b. Na$^{+}$ and O$^{2-}$

Answers

1. the ratio of each kind of ion in the compound
2. Sometimes more than one ion is needed to balance the charge on the other ion in an ionic compound.
3. a. MgI$_2$
   b. Na$_2$O

Key Takeaways

- Proper chemical formulas for ionic compounds balance the total positive charge with the total negative charge.
- Groups of atoms with an overall charge, called polyatomic ions, also exist.

Exercises

1. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. Na$^+$ and Br$^-$
2. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. K\(^+\) and Cl\(^-\)
   b. Mg\(^{2+}\) and Cl\(^-\)
   c. Mg\(^{2+}\) and Se\(^{2-}\)

3. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. Na\(^+\) and N\(^3-\)
   b. Mg\(^{2+}\) and N\(^3-\)
   c. Al\(^{3+}\) and S\(^2-\)

4. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. Li\(^+\) and N\(^3-\)
   b. Mg\(^{2+}\) and P\(^3-\)
   c. Li\(^+\) and P\(^3-\)

5. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. Fe\(^{3+}\) and Br\(^-\)
   b. Fe\(^{2+}\) and Br\(^-\)
   c. Au\(^{3+}\) and S\(^2-\)
   d. Au\(^+\) and S\(^2-\)

6. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. Cr\(^{3+}\) and O\(^{2-}\)
   b. Cr\(^{2+}\) and O\(^{2-}\)
   c. Pb\(^{2+}\) and Cl\(^-\)
   d. Pb\(^{4+}\) and Cl\(^-\)

7. Write the chemical formula for the ionic compound formed by each pair of ions.
   a. Cr\(^{3+}\) and NO\(_3^-\)
   b. Fe\(^{2+}\) and PO\(_4^{3-}\)
   c. Ca\(^{2+}\) and CrO\(_4^{2-}\)
   d. Al\(^{3+}\) and OH\(^-\)

8. Write the chemical formula for the ionic compound formed by each pair of ions.
9. For each pair of elements, determine the charge for their ions and write the proper formula for the resulting ionic compound between them.
   a. Ba and S
   b. Cs and I

10. For each pair of elements, determine the charge for their ions and write the proper formula for the resulting ionic compound between them.
   a. K and S
   b. Sc and Br

11. Which compounds would you predict to be ionic?
   a. Li₂O
   b. (NH₄)₂O
   c. CO₂
   d. FeSO₃
   e. C₆H₆
   f. C₂H₆O

12. Which compounds would you predict to be ionic?
   a. Ba(OH)₂
   b. CH₂O
   c. NH₂CONH₂
   d. (NH₄)₂CrO₄
   e. C₈H₁₈
   f. NH₃

Answers

1.
   a. NaBr
   b. MgBr₂
   c. MgS
3.  
   a. Na$_3$N  
   b. Mg$_3$N$_2$  
   c. Al$_2$S$_3$  

5.  
   a. FeBr$_3$  
   b. FeBr$_2$  
   c. Au$_2$S$_3$  
   d. Au$_2$S  

7.  
   a. Cr(NO$_3$)$_3$  
   b. Fe$_3$ (PO$_4$)$_2$  
   c. CaCrO$_4$  
   d. Al(OH)$_3$  

9.  
   a. Ba$^{2+}$, S$^{2-}$, BaS  
   b. Cs$^+$, I$^-$, CsI  

11.  
    a. ionic  
    b. ionic  
    c. not ionic  
    d. ionic  
    e. not ionic  
    f. not ionic  

3.4: Ionic Nomenclature

Concept Review Exercises

1. Briefly describe the process for naming an ionic compound.
2. In what order do the names of ions appear in the names of ionic compounds?

3. Which ionic compounds can be named using two different systems? Give an example.

**Answers**

1. Name the cation and then the anion but don’t use numerical prefixes.

2. the cation name followed by the anion name

3. Ionic compounds in which the cation can have more than one possible charge have two naming systems. FeCl$_3$ is either iron(III) chloride or ferric chloride (answers will vary).

**Key Takeaway**

- Each ionic compound has its own unique name that comes from the names of the ions.

**Exercises**

1. Name each ion.
   
   a. Ra$^{2+}$
   
   b. P$^{3-}$
   
   c. H$_2$PO$_4^-$
   
   d. Sn$^{4+}$

2. Name each ion.
   
   a. Cs$^+$
   
   b. As$^{3-}$
   
   c. HSO$_4^-$
   
   d. Sn$^{2+}$

3. Name the ionic compound formed by each pair of ions.
   
   a. Na$^+$ and Br$^-$
   
   b. Mg$^{2+}$ and Br$^-$
   
   c. Mg$^{2+}$ and S$^{2-}$

4. Name the ionic compound formed by each pair of ions.
   
   a. K$^+$ and Cl$^-$
   
   b. Mg$^{2+}$ and Cl$^-$
5. Name the ionic compound formed by each pair of ions.
   a. Na\(^+\) and N\(^3-\)
   b. Mg\(^{2+}\) and N\(^3-\)
   c. Al\(^{3+}\) and S\(^{2-}\)

6. Name the ionic compound formed by each pair of ions.
   a. Li\(^+\) and N\(^3-\)
   b. Mg\(^{2+}\) and P\(^{3-}\)
   c. Li\(^+\) and P\(^{3-}\)

7. Name the ionic compound formed by each pair of ions. Use both the Stock and common systems, where appropriate.
   a. Fe\(^{3+}\) and Br\(^-\)
   b. Fe\(^{2+}\) and Br\(^-\)
   c. Au\(^{3+}\) and S\(^{2-}\)
   d. Au\(^+\) and S\(^{2-}\)

8. Name the ionic compound formed by each pair of ions. Use both the Stock and common systems, where appropriate.
   a. Cr\(^{3+}\) and O\(^{2-}\)
   b. Cr\(^{2+}\) and O\(^{2-}\)
   c. Pb\(^{2+}\) and Cl\(^-\)
   d. Pb\(^{4+}\) and Cl\(^-\)

9. Name the ionic compound formed by each pair of ions. Use both the Stock and common systems, where appropriate.
   a. Cr\(^{3+}\) and NO\(_3^-\)
   b. Fe\(^{2+}\) and PO\(_4^{3-}\)
   c. Ca\(^{2+}\) and CrO\(_4^{2-}\)
   d. Al\(^{3+}\) and OH\(^-\)

10. Name the ionic compound formed by each pair of ions. Use both the Stock and common systems, where appropriate.
    a. NH\(_4^+\) and NO\(_3^-\)
    b. H\(^+\) and Cr\(_2\)O\(_7^{2-}\)
c. Cu$^+$ and CO$_3^{2-}$  
d. Na$^+$ and HCO$_3^-$

11. Give two names for each compound.
   a. Al(HSO$_4$)$_3$
   b. Mg(HSO$_4$)$_2$

12. Give two names for each compound.
   a. Co(HCO$_3$)$_2$
   b. LiHCO$_3$

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**Answers**

1.  
   a. the radium ion  
   b. the phosphide ion  
   c. the dihydrogen phosphate ion  
   d. the tin(IV) ion or the stannic ion

3.  
   a. sodium bromide  
   b. magnesium bromide  
   c. magnesium sulfide

5.  
   a. sodium nitride  
   b. magnesium nitride  
   c. aluminum sulfide

7.  
   a. iron(III) bromide or ferric bromide  
   b. iron(II) bromide or ferrous bromide  
   c. gold(III) sulfide or auric sulfide  
   d. gold(I) sulfide or aurous sulfide

9.
a. chromium(III) nitrate or chromic nitrate
b. iron(II) phosphate or ferrous phosphate
c. calcium chromate
d. aluminum hydroxide

11.

a. aluminum hydrogen sulfate or aluminum bisulfate
b. magnesium hydrogen sulfate or magnesium bisulfate

3.5: Formula Mass

Concept Review Exercises

1. What is the relationship between atomic mass and formula mass?

2. How are subscripts used to determine a formula mass when more than one polyatomic ion is present in a chemical formula?

Answers

1. The formula mass is the sum of the atomic masses of the atoms in the formula.

2. The subscript is distributed throughout the parentheses to determine the total number of atoms in the formula.

Key Takeaway

• Formula masses of ionic compounds can be determined from the masses of the atoms in their formulas.

Exercises

1. What is the formula mass for the ionic compound formed by each pair of ions?
   a. Na⁺ and Br⁻
   b. Mg²⁺ and Br⁻
   c. Mg²⁺ and S²⁻

2. What is the formula mass for the ionic compound formed by each pair of ions?
   a. K⁺ and Cl⁻
   b. Mg²⁺ and Cl⁻
   c. Mg²⁺ and Se²⁻
3. What is the formula mass for the ionic compound formed by each pair of ions?
   a. Na\(^+\) and N\(^3-\)
   b. Mg\(^{2+}\) and N\(^3-\)
   c. Al\(^{3+}\) and S\(^2-\)

4. What is the formula mass for the ionic compound formed by each pair of ions?
   a. Li\(^+\) and N\(^3-\)
   b. Mg\(^{2+}\) and P\(^3-\)
   c. Li\(^+\) and P\(^3-\)

5. What is the formula mass for each compound?
   a. FeBr\(_3\)
   b. FeBr\(_2\)
   c. Au\(_2\)S\(_3\)
   d. Au\(_2\)S

6. What is the formula mass for each compound?
   a. Cr\(_2\)O\(_3\)
   b. CrO
   c. PbCl\(_2\)
   d. PbCl\(_4\)

7. What is the formula mass for each compound?
   a. Cr(NO\(_3\))\(_3\)
   b. Fe\(_3\)(PO\(_4\))\(_2\)
   c. CaCrO\(_4\)
   d. Al(OH)\(_3\)

8. What is the formula mass for each compound?
   a. NH\(_4\)NO\(_3\)
   b. H\(_2\)Cr\(_2\)O\(_7\)
   c. Cu\(_2\)CO\(_3\)
   d. NaHCO\(_3\)

9. What is the formula mass for each compound?
   a. Al(HSO\(_4\))\(_3\)
   b. Mg(HSO\(_4\))\(_2\)

10. What is the formula mass for each compound?
a. \( \text{Co(HCO}_3\text{)}_2 \)
b. \( \text{LiHCO}_3 \)

Answers

1.
   a. 102.90 amu
   b. 184.11 amu
   c. 56.38 amu

3.
   a. 83.00 amu
   b. 100.93 amu
   c. 150.17 amu

5.
   a. 295.50 amu
   b. 215.60 amu
   c. 490.30 amu
   d. 426.10 amu

7.
   a. 238.00 amu
   b. 357.49 amu
   c. 156.08 amu
   d. 78.01 amu

9.
   a. 318.22 amu
   b. 218.47 amu

3.6: Chapter Summary
Q3.1.1
Why is an ionic compound unlikely to consist of two positively charged ions?

A3.1.1
Positive charges repel each other, so an ionic compound is not likely between two positively charged ions.

H3.1.1
Think of Coulomb's law.

S3.1.1
Coulomb's law relates the force of interaction between two charged species.

\[ F = \frac{Q_1 Q_2}{4\pi \varepsilon R_{12}} \]

Hence there is a repulsion \(-F\) between species of same polarity.

Q3.1.2
Why is an ionic compound unlikely to consist of two negatively charged ions?

Q3.1.3
A calcium atom has two valence electrons. Do you think it will lose two electrons or gain six electrons to obtain an octet in its outermost electron shell?

A3.1.3: It is more likely to lose two electrons.

Q3.1.4
An aluminum atom has three valence electrons. Do you think it will lose three electrons or gain five electrons to obtain an octet in its outermost electron shell?

Q3.1.5
A selenium atom has six valence electrons. Do you think it will lose six electrons or gain two electrons to obtain an octet in its outermost electron shell?

A3.1.5: It is more likely to gain two electrons.
Q3.1.6

An iodine atom has seven valence electrons. Do you think it will lose seven electrons or gain one electron to obtain an octet in its outermost electron shell?